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Temporal Dynamics of Rod and Cone Photoreceptor Interactions Under Mesopic Illumination

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Abstract

Purpose: Photoreceptor interactions reduce the temporal bandwidth of the visual system under mesopic illumination. The dynamics of these interactions are not clear. This study investigated cone-cone and rod-cone interactions when the rod (R) and three cone (L, M, S) photoreceptor classes contribute to vision via shared post-receptoral pathways.

Methods:A four-primary photostimulator independently controlled photoreceptor activity in human observers. To determine the temporal dynamics of receptoral (L, S, R) and post-receptoral (LMS, LMSR, +L-M) pathways (5 Td, 7° eccentricity) in Experiment 1, ON-pathway sensitivity was assayed with an incremental probe (25ms) presented relative to onset of an incremental sawtooth conditioning pulse (1000ms). To define the post-receptoral pathways mediating the rod stimulus, Experiment 2 matched the color appearance of increased rod activation (30% contrast, 25-1000ms; constant cone excitation) with cone stimuli (variable L+M, L/L+M, S/L+M; constant rod excitation).

Results: Cone-cone interactions with luminance stimuli (LMS, LMSR, L-cone) reduced Weber contrast sensitivity by 13% and the time course of adaptation was 23.7±1ms (μ±SE). With chromatic stimuli (+L-M, S), cone pathway sensitivity was also reduced and recovery was slower (+L-M 8%, 2.9±0.1ms; S 38%, 1.5±0.3ms). Threshold patterns at ON-conditioning pulse onset were monophasic for luminance and biphasic for chromatic stimuli. Rod-rod interactions increased sensitivity (19%) with a recovery time of 0.7±0.2ms. Compared to cone-cone interactions, rod-cone interactions with luminance stimuli reduced sensitivity to a lesser degree (5%) with faster recovery (42.9±0.7ms). Rod-cone interactions were absent with chromatic stimuli. Experiment 2 showed that rod activation generated luminance (L+M) signals at all durations, and chromatic signals (L/L+M, S/L+M) for durations >75ms.

Conclusions: Temporal dynamics of cone-cone interactions are consistent with contrast sensitivity loss in the MC pathway for luminance stimuli and chromatically opponent responses in the PC and KC pathway with chromatic stimuli. Rod-cone interactions limit contrast sensitivity loss during dynamic illumination changes and increase the speed of mesopic light adaptation. The change in relative weighting of the temporal rod signal within the major post-receptoral pathways modifies the sensitivity and dynamics of photoreceptor interactions.

Keywords: temporal vision • photoreceptors: visual performance • adaptation: chromatic